BRH/DBE 70-4

PB195967

Doses to the Central Nervous System of Children Resulting from X-Ray Therapy for Tinea Capitis

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

TECHNICAL REPORTS

Technical reports published by the Division of Biological Effects, Bureau of Radiological Health, are available from the National Technical Information Service (formerly the Clearinghouse for Federal Scientific and Technical Information), Springfield, Va. 22151. The price is $3.00 for paper copy and $0.65 for microfiche. Prices are available from NTIS for bulk orders. The PB number, if indicated for a report, should be cited when ordering.

PHS 1672 Radiological Health Research, Summary Report, July 1965 - December 1966 (PB 183 795)

PHS 1809 Radiation Bio-Effects Summary Report, January - December 1967 (PB 183 796)

PHS 1809 Radiation Bio-Effects Summary Report, January - December 1968 (PB 183 797)

TSB-68-4 Biological Aspects of Microwave Radiation, A Review of Hazards (PB 185 964)

DBE 69-1 Biological Aspects of Laser Radiation, A Review of Hazards (PB 184 003)

DBE 69-2 Evaluation of a Possible Causal Relationship between Fallout Deposition of Strontium 90 and Infant and Fetal Mortality Trends (PB 188 974)

DBE 70-1 Radiation Bio-Effects Summary Report, January - December 1969 (PB 190 110)

DBE 70-2 Biological Effects and Health Implications of Microwave Radiation (PB 193 898)

DBE 70-3 Biological Aspects of Ultraviolet Radiation. A Review of Hazards (PB 194 611)

DBE 70-4 Doses to the Central Nervous System of Children Resulting from X-Ray Therapy for Tinea Capitis

BRH/DBE 70-4

Doses to the Central Nervous System of Children Resulting from X-Ray Therapy for Tinea Capitis

by

Wah Lee and H.D. Youmans
Division of Biological Effects
Bureau of Radiological Health

October 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Environmental Control Administration
Bureau of Radiological Health
Rockville, Maryland 20852

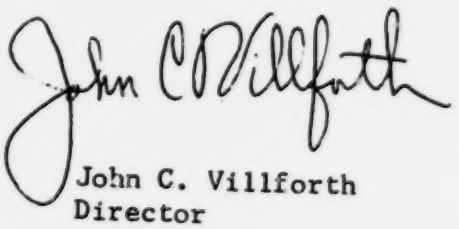
FOREWORD

The Bureau of Radiological Health conducts a national program to limit man's exposure to ionizing and nonionizing radiations. To this end, the Bureau (1) develops criteria and recommends standards for safe limits of radiation exposure, (2) develops methods and techniques for controlling radiation exposure, (3) plans and conducts research to determine health effects of radiation exposure, (4) provides technical assistance to agencies having radiological health programs, and (5) conducts an electronic product radiation control program to protect the public health and safety.

The Bureau publishes its findings monthly in Radiological Health Data and Reports, appropriate scientific journals, and from time to time in Division-sponsored technical reports.

The technical reports published by the Division of Biological Effects contain information generated by the Division staff which is timely and useful to the radiological health program. Subjects covered by these reports are varied, for the Division is charged with developing--through animal investigations and population studies--knowledge of the biological effects of radiation delivered to man from his environment and from his use of substances and devices that emit radiation. The reports are distributed to persons and repositories that have expressed an interest in the biological effects of radiation; in addition, the reports are available from the National Technical Information Service.

Readers are encouraged to report omissions or errors to the Bureau. Additional comments or requests for further information are also solicited.



John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The Division of Biological Effects is the biological research arm of the Bureau of Radiological Health. The Division investigates primarily the effects of low radiation doses where subtle alterations are more often the rule than the exception. The Division supports experimental radiobiology and epidemiology studies which contribute to public health. The investigations conducted in-house and by contract examine various aspects of short- and long-term radiation effects in several animal species and in man. These investigations produce data which contribute to the knowledge of the effects of ionizing and nonionizing radiation exposure and provide supportive health effects information for the development of radiation exposure standards.

This report details research on x-ray doses to organs of the heads of children epilated with radiation as treatment for tinea capitis. Another study of the Division showed that the lipid composition of beagle pup brain irradiated in vivo is altered by radiation doses comparable to those received by the children. We are currently supporting an epidemiologic study of many thousands of persons in Israel who were x-ray epilated in their youth. Another epidemiologic investigation, conducted elsewhere, has indicated a substantial increase in neurological disorder and cancer in patients previously irradiated for tinea. Together, this information is intended to elucidate the consequences of x-ray exposure to the young.

William A. Mills

William A. Mills, Ph.D.
Director
Division of Biological Effects

ACKNOWLEDGMENT

The authors are indebted to Miss Lynda Kramer and Mr. James Rolofson for their technical assistance in the collection of data and preparation of figures, and to Mr. Richard Chiacchierini for the statistical analyses. We would also like to thank Mr. Donald Hodge for editorial assistance.

DISCLAIMER

The use of commercial products or mention of private firms in no way constitutes endorsement by the U.S. Public Health Service or its affiliates.

CONTENTS

FOREWORD iii
PREFACE v

INTRODUCTION 1
METHODS 2
RESULTS 7
DISCUSSION 12
REFERENCES 14

TABLES

1. Dimensions of Phantoms, Ages 3, 6, and 12 Years 3

FIGURES

1. Adamson-Kienbock five-field treatment technique 2
2. Photograph of the three head phantoms used in this study 3
3. A 47 keV monoenergetic photon spectrum from the emission of ^{210}Pb 5
4. A 57 kVp x-ray spectrum taken with an expanded scale spectrometer display which makes a distinct separation of the base line channels from those of the spectrum 5
5. Comparison of two radiation spectra 8
6. Mean dose to the brains as functions of kVp and HVT 9
7. Dose distribution in the 3-, 6-, and 12-year-old brain phantoms 10
8. Doses to the eye, the thyroid, and the pituitary as functions of kVp and HVT 11

DOSES TO THE CENTRAL NERVOUS SYSTEM OF CHILDREN RESULTING FROM X-RAY THERAPY FOR TINEA CAPITIS

INTRODUCTION

Historical Background

Tinea capitis (ringworm of the scalp) is a benign fungal infection of the scalp common to prepubescent children. It is not geographically indigenous and has occurred in epidemics. Before 1958, when griseofulvin became available for ringworm treatment, patients were routinely epilated by x-ray exposure of the scalp. During epidemics the technique was also used prophylactically, and it is estimated that over 200,000 children have been irradiated, some more than once (3). Zugerman (21) reported that children often developed severe headache, nausea, and vomiting following x-ray therapy. A recent epidemiologic study by Albert and Omran (1) indicated that the irradiated patients suffered an increase in mental disorder, cancer, and permanent partial alopecia. A study recently conducted in this laboratory has shown that the lipid composition of beagle pup brain irradiated in vivo is altered by radiation doses comparable to those received by children treated for tinea capitis (13). Currently we are supporting an epidemiologic study of more than 20,000 children irradiated for tinea capitis in Israel. Hopefully, the results of the study will elucidate the degree of risk inherent in x-ray scalp epilation of the young.

Most tineal epilations employed an approximation to the Adamson-Kienbock technique. This method requires the spacing of five radiation fields evenly on the scalp (Fig. 1). Source-to-skin distance of 20-25 cm and field size of about 20 cm diameter are typical. Skin exposures of 300-500 R per field and a beam quality of 1.0 mm Al half-value thickness (HVT) have been recommended (19). A majority of the radiation therapy employed beam qualities of 70-100 kVp and HVT's of 0.6-1.0 mm Al (14). However, it has been reported that beam qualities of 60-135 kVp, 0.5-5.0 mm Al HVT have been used (5).

Purpose and Scope

The purpose of this study is to develop a method for estimating brain, lens of eye, and thyroid doses in children of various ages (skull sizes and development) and for a range of x-ray beam qualities approximating those used in tineal treatment. The results may be used to approximate organ doses for other x-ray techniques within the range of variables considered.

To meet these objectives, x-ray beam qualities of 70 to 120 kVp with half-value thicknesses of 0.66 to 3.9 mm of Al were used to irradiate head phantoms of 3-, 6-, and 12-year-old children. The doses to various portions of the head were studied as functions of x-ray beam quality, skull size, and development.

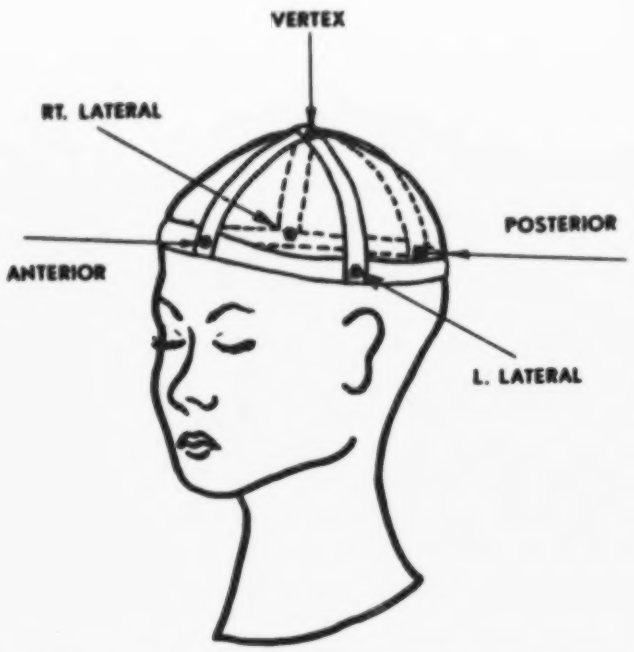


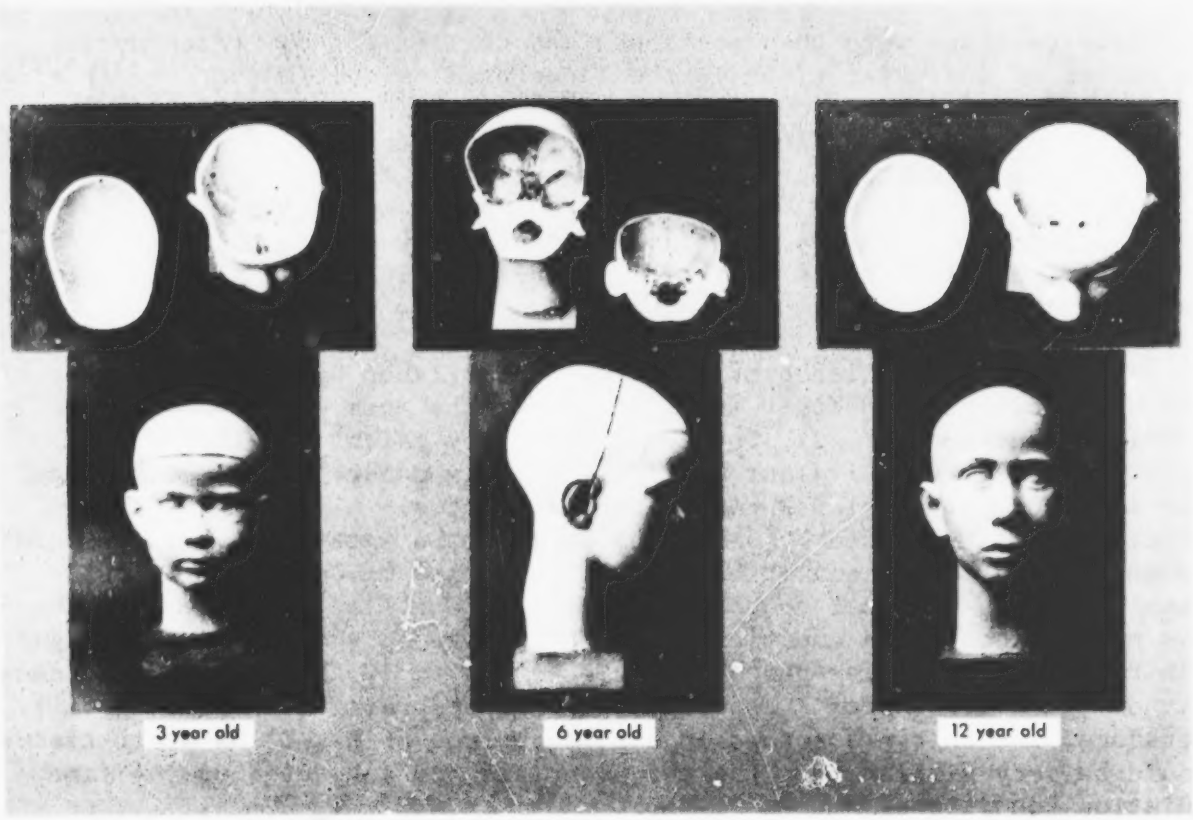
Figure 1. Adamson-Kienbock five-field treatment technique. The five field-centering points are equal distance from their neighboring points. The five points are usually marked on the scalp of the patient with the aid of a treatment "cap."

METHODS

Phantom Construction

Phantoms for this study were constructed from the skulls of 3-, 6-, and 12-year-old children (Fig. 2). The dimensions of these three head phantoms (Table 1) adequately represent the head dimensions of similarly aged children x-ray epilated for tinea capitis. As indicated by Table 1, cranium thickness and brain size increase more between the ages of 3 and 6 than between 6 and 12. In fact, the brains of the 6- and 12-year-old are nearly the same size. However, the increase in mean cranium thickness between the 6- and 12-year-old indicate that the skull is still developing. As will be shown later, the differences in cranium thickness and brain size contribute to dose changes in phantoms irradiated under the same conditions.

The soft tissue for the phantoms was constructed from Mix-D, a mixture of paraffin, polyethylene, MgO, and TiO_2. Mix-D brains were cast in plaster molds made from silicone rubber castings of the cranial vaults.



NOT REPRODUCIBLE

Figure 2. Photograph of the three head phantoms used in this study. Mix-D was used as soft tissue material for phantom construction.

TABLE 1. DIMENSIONS OF PHANTOMS, AGES 3, 6, AND 12 YEARS

Phantom Age, yr	Max. Dia., cm AP	Lat	Cranium Thickness, cm Mean	Range	Mean Scalp Thickness (Mix-D), mm	Estimated Brain Mass,[a] g
3	15.5	12.0	2.4	1.5-3.0	4 ± 1	1055
6	16.0	12.5	2.9	2.5-4.0	4 ± 1	1136
12	16.5	13.0	3.3	2.5-4.0	4 ± 1	1140

a. The mass of the brains in the phantoms was estimated by measuring volume of the skull cavities in the phantoms.

The brain castings were then sectioned and drilled for dosimeter access. The number of dosimeter sites in the three phantoms varied with brain size because an attempt was made to maintain the same inter-dosimeter spacing and anatomic location. Each brain was divided into three upper and three lower sections. Forty-four sites were drilled in the 3-year-old phantom, 45 in the 6-year-old, and 49 in the 12-year-old. Mix-D plugs were used to fill empty dosimeter holes. Preliminary dosimetry showed that the dosimeters did not perturb the radiation field significantly in the phantom brain.

The tissue equivalence of Mix-D was established by Jones and Raine (10) and Loevinger and Yaniv (11). By using the mass energy absorption coefficients of Berger (2), Loevinger and Yaniv calculated that Mix-D was a better water equivalent material than six other "tissue equivalent" materials commonly employed for phantom dosimetry. Also, Mix-D was experimentally established by Jones and Raine to be water equivalent within a wide range of x-ray qualities (0.5 mm Al to 1.0 mm Cu HVT). Calculations using the chemical composition data of Long (12) indicate that the mass energy absorption coefficients of brain are only a few percent higher than those of water over photon energies of 10 to 100 keV. Also, the density of Mix-D (0.99 g/cm^3) approximates that of brain tissue (1.0 g/cm^3). Therefore, the energy absorbed in a given volume of Mix-D and brain tissue should be very similar when the two materials are subjected to the same radiation conditions.

Equipment Calibration

The superficial therapy x-ray machine employed in our study is similar to many used for patient irradiations (14). The machine, a Picker "Zephyr" model NR-2, has an oil cooled PX-2A x-ray tube, with an inherent filtration equivalent to 0.5 mm Al. The single-phase, 220-volt power supply to the x-ray unit was stabilized by a vacuum-tube regulated constant voltage transformer. Because this model does not employ a satisfactory x-ray tube-current stabilizer, a transistorized (MOSFET) tube-current stabilizer of our design was added to the control circuits.

The peak potential (kVp) across the x-ray tube was calibrated with a Victoreen SCIPP 1600 spectrometer coupled to a Ge(Li) solid-state detector cooled with liquid nitrogen. The energy scale of the spectrometer, calibrated with monoenergetic photons from ^{210}Pb (47 keV), ^{57}Co (14.4 keV and 121.6 keV), and ^{109}Cd (88.0 keV), was found to be linear within this range of photon energies.

A calibration spectrum of ^{210}Pb is presented in Fig. 3. The 47.0 keV spectrum of ^{210}Pb resembles a line with its peak height at channel 75 and has no counts above the base-line level beyond channel 76. The highest channel containing counts above the base-line level in a given spectrum corresponds to the maximum energy of that spectrum. Therefore, when the relationship of a series of known monoenergetic photon spectra and their corresponding highest channels containing counts above the base line level

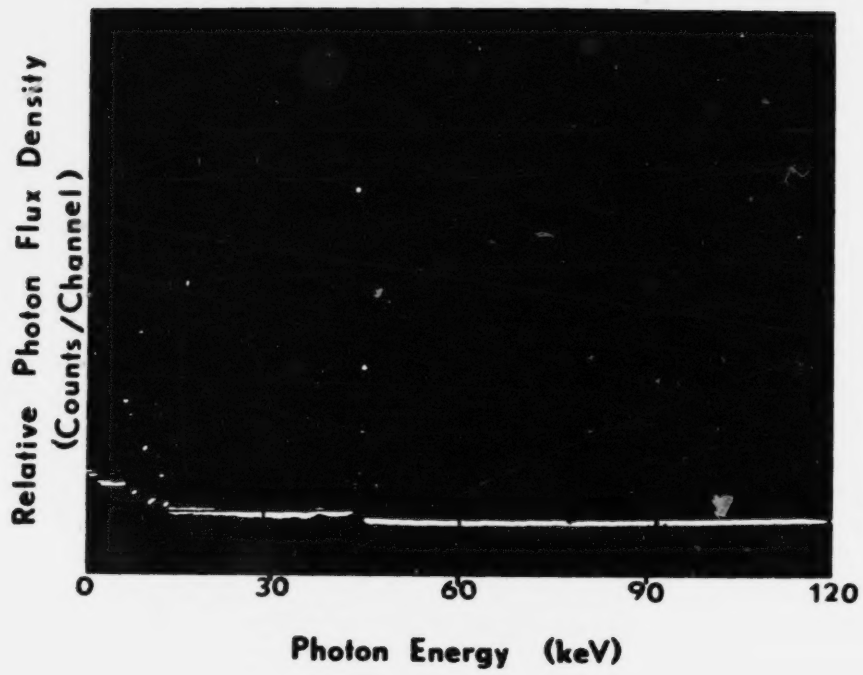


Figure 3. A 47 keV monoenergetic photon spectrum from the emission of ^{210}Pb. Scale of calibration: 0.6 keV per channel. Detector: Ge(Li) cooled with liquid nitrogen.

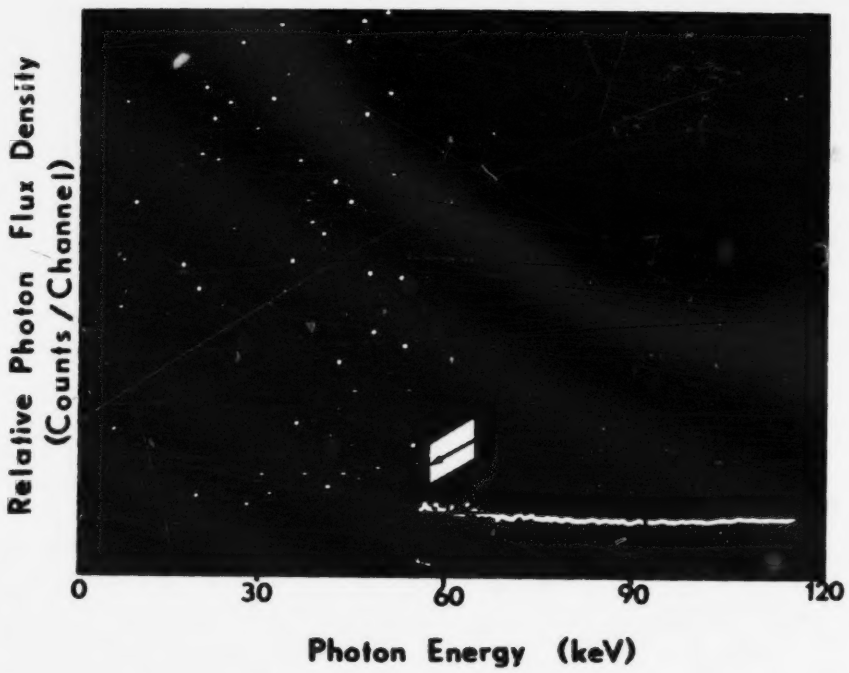


Figure 4. A 57 kVp x-ray spectrum taken with an expanded scale spectrometer display which makes a distinct separation of the base line channels from those of the spectrum. The maximum photon energy of the spectrum corresponding to the maximum potential across the x-ray tube (kVp) is determined by observing the highest channel containing counts above the base line as indicated by the arrow.

are determined, the maximum energy of an unknown photon spectrum can be established from the highest channel registered in the spectrometer. Fig. 4 is a 57 kVp x-ray spectrum taken with an expanded vertical scale of the spectrometer display. This technique brings out a distinct separation of the base-line channels from those of the spectrum. The highest channel containing counts above the base-line in a given x-ray spectrum was observed to shift no more than one channel within the count rates of 300-3000 counts per minute (the count rates commonly employed in our spectral measurements) and for a total count up to 50,000. One channel in Fig. 4 corresponds to 0.6 keV, which is the approximate uncertainty for this method of calibrating the peak potential (kVp) across the x-ray tube in this study.

Dosimeter Calibration

All primary beam exposures were measured with an electrometer (Victoreen M-570) and either a low or a medium energy ionization chamber (Victoreen M-651 and M-154, respectively) depending on the beam quality. These instruments were calibrated by the U.S. National Bureau of Standards. Half-value thicknesses were determined from transmission data obtained with 99.9+% Al (Materials Research Corporation, rolled spectroscopic rod).

Lithium fluoride powder (TLD-100) in small, thin, gelatin capsules (size No. 5) was employed for in-phantom exposure measurements. The dosimeters were calibrated in air against the medium energy ionization chamber with a beam quality of 100 kVp, 3.5 mm Al HVT. The choice of this HVT was based on estimates of the in-phantom radiation qualities by the "cap on - cap off" method of Clarkson and Mayneord (4) with brass caps and LiF-gelatin dosimeters. HVT's in a head phantom ranged from 2.1 to 4.3 mm Al for primary beam qualities of 0.66 to 3.9 mm Al used in this study. Dosimiters calibrated with a beam quality of 3.5 mm Al HVT exhibited a quality dependence of less than 2% in the 2.1 to 4.3 mm Al HVT range. The exposure-to-dose conversion factor, $\bar{f}$ (rad/R), for water varies little over the range of photon energies used. The values of $\bar{f}$ at 30 keV and 40 keV are 0.87 rad/R and 0.88 rad/R, respectively (8). The in-phantom range of effective photon energies is 28-38 keV. Thus, an $\bar{f}$ of 0.88 rad/R was selected for all absorbed dose calculations. The LiF-gelatin dosimeter dose response was found to be linear below 600 R; consequently, a fixed exposure of 100 R was used for dosimeter calibration. All LiF powder was read-out in a nitrogen atmosphere. Usually the reproducibility of two 35 mg aliquots taken from each 105 mg capsule loading varied between 1 and 2%.

Conditions of Irradiation

The following set of irradiation conditions were used for all phantom measurements. The skin exposure was 400 R to each of the five fields shown in Fig. 1. Treatment caps, also shown in Fig. 1, were used to assure correct geometry for a fixed source-to-skin distance (SSD) of 22 cm and a corresponding field size 18 cm in diameter. The three x-ray beam

qualities were: 72 kVp, 0.66 mm Al HVT; 99.5 kVp, 1.00 mm Al HVT; and 118.5 kVp, 3.90 mm Al HVT. A 0.5 mm thick lead sheet commonly used in clinical practice was placed over the face and ears of the phantom during irradiation. Three complete sets of data were obtained for each combination of skull age and beam quality.

Penetrability Index

In the graphical presentation of data, we indicate beam penetrability by the product of x-ray tube potential and first half-value thickness. We term the product "penetrability index" and its units are kVp mm Al. The usefulness of this procedure will become clear in a later section which discusses the application of these data to the Adamson-Kienbock technique employed at beam qualities other than those used in this investigation. For most clinical purposes, beam quality is measured quantitatively to permit the selection of a suitable depth dose table (6). In some cases, a wide range of coordinate tube potentials and half-value thicknesses pertain to a single depth dose tabulation. Proctor and Greening (15) and Greening (7) have shown that two and sometimes three parameters, or a spectrum is necessary to specify beam quality accurately.

In tineal scalp epilations, the narrow range of radiation beam qualities commonly employed for therapy permit some relaxation of such stringent requirements. However, these considerations lead one to realize that depth dose data are crude indices of x-ray beam quality, and that some care should be exercised in applying the graphical data of this study to all possible products of high voltage and half-value thickness. The overlay of spectra in Fig. 5 shows appreciable similarity in the extremes of the primary beam qualities used, and we feel that the "penetrability index" is adequate for the purposes of this study; the tabular insert in Fig. 6 provides sufficient qualifying information.

RESULTS

Brain Dose

Average brain dose as a function of x-ray beam quality is given in Fig. 6. The mean brain doses shown for techniques 1, 2, and 3 (tabular insert, Fig. 6) are the arithmetic averages of three complete sets of measurements. The estimated standard error of the three sets is about 4% of the mean value. Techniques 4, 5, and 6 were used to provide data at other tube potentials and filtrations; these data consist of a single measurement, and are within 5% of the graphically interpolated values.

In general, the dose distribution is quite symmetrical with respect to the vertical axis. Doses to the upper half are much higher than those to the lower half. This is due to the depth-dose effect and the effect of shielding the lower half of the head with the lead sheet.

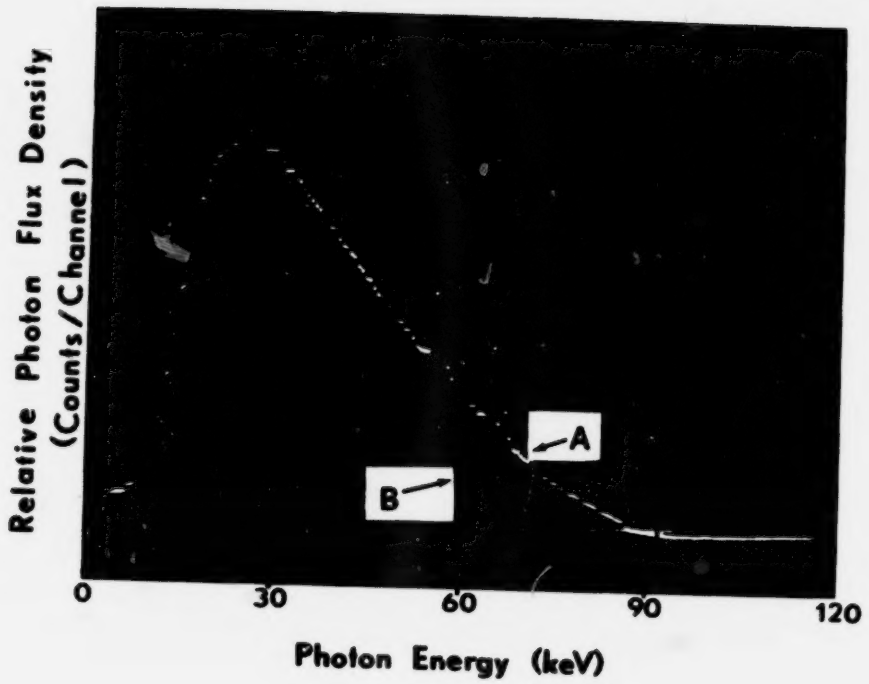


Figure 5. Comparison of two radiation spectra: A. 95.5 kVp; 1.00 mm Al HVT (0.12 mm Al added filtration). B. 78.3 kVp; 1.07 mm Al HVT (0.51 mm Al added filtration). Inherent filtration in the machine is about 0.5 mm Al equivalent. Note the distinct separation of the K_α and K_β doublet of tungsten in spectrum A. In spectrum B the characteristic radiation of tungsten is very small due to the low peak energy of the spectrum.

The data in Figs. 6 and 7 can be used to estimate both average brain dose and the dose at any of the 40-odd dosimeter sites. This estimation is possible because in a given phantom the ratio of any two mean brain doses corresponding to any two x-ray techniques used was found to be approximately equal to the ratio of the doses at any dosimeter site. Therefore, the ratio of any mean brain dose to one of the whole-brain averages given in Fig. 7 may be used as a scaling factor for all the site values. For example, Fig. 6 indicates a mean brain dose of 80.1 rads for the 3-year-old phantom irradiated with a beam of 72 kVp, 0.66 mm Al HVT (penetrability index: 47.5). By using Fig 7A the ratio of their mean brain doses is 80.1/147, which is the scaling factor.

This method of estimating dose distribution in the brain from the mean brain doses seems valid in all the phantoms between any two beam qualities employed in this study. It is particularly effective when the range of beam qualities is limited to 72-98.5 kVp with HVT's of 0.66-1.28 mm Al (the most common techniques employed in patient therapy).

Within this limited range of beam qualities, the root mean squared deviation of the estimated values from the measured means (techniques 1, 4, 5, 6) averaged 4.8% for all dosimeter sites in the brain.

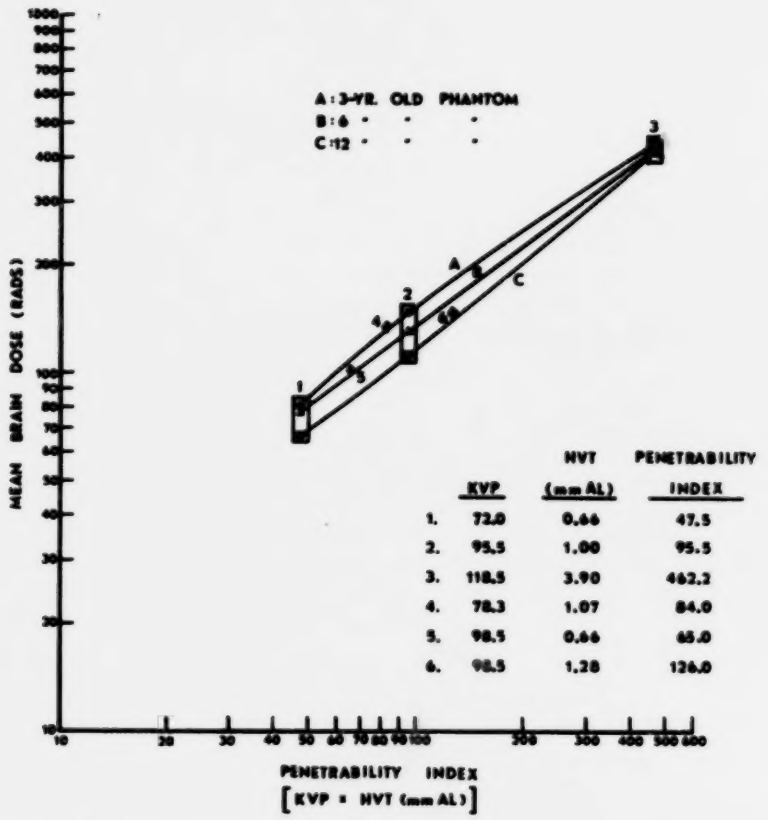


Figure 6. Mean dose to the brains as functions of kVp and HVT. The penetrability index is defined as the product of kVp and HVT (in mm Al). The numbers on the curves refer to the x-ray techniques as described at the bottom of the figure.

Eye, Thyroid, and Pituitary Doses

Figure 8 presents average doses for the eye, thyroid, and pituitary. Again, three sets of measurements have been averaged for techniques 1, 2, and 3 (Fig. 6). The letters A, B, and C in the figure indicate skull ages 3, 6, and 12 years, respectively. These organ doses are primarily due to radiation scattered from the working beam by the skull and brain. Individual differences in skull and facial shapes exert a greater influence on peripheral organ doses than on brain dose. Consequently,

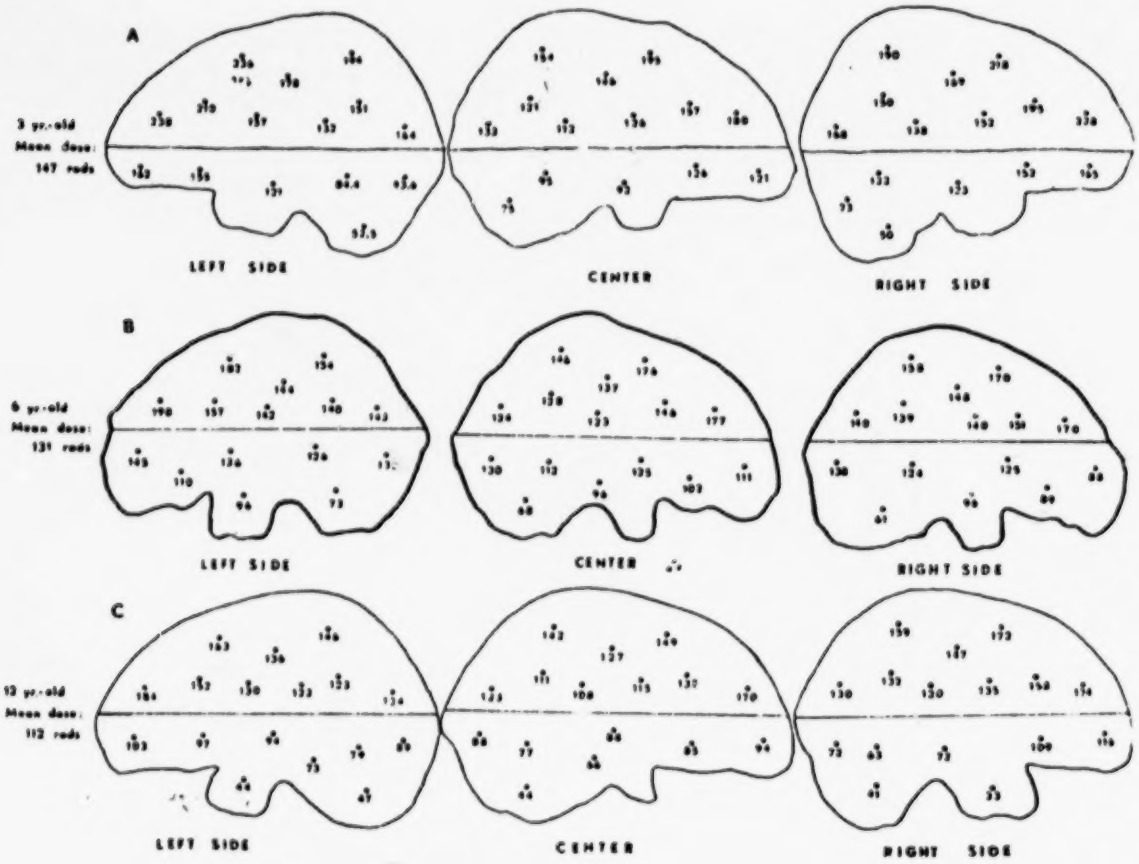


Figure 7. Dose distribution in the 3-, 6-, and 12-year-old brain phantoms. The numbers in the figure are in rads. Note the dose symmetry along the vertical axis in the brain phantoms. Irradiation technique: 95.5 kVp, 1.00 mm Al HVT. Figure 7A can be used for the ages of 3-4, 7B for ages 5-8, and 7C for ages 9-12.

greater uncertainties exist in these organ dose measurements. The estimated standard errors for the eye, thyroid, and pituitary doses are 6%, 9%, and 11% of the mean doses, respectively. In Fig. 8, the thyroid doses in the 12-year-old phantom are larger than those for the 6-year-old. This is due to the arbitrarily chosen dimensions for phantom construction in which the 6-year-old phantom has a longer neck and therefore a greater distance of the thyroid from the skull. Pituitary dose was not measured in the 6-year-old phantom. However, from the similarities in cranium thickness, brain size (Table 1), and eye doses of the 6- and 12-year-old phantoms (Fig. 8), doses to the pituitary in the 6-year-old phantom should be very similar to those of the 12-year-old one.

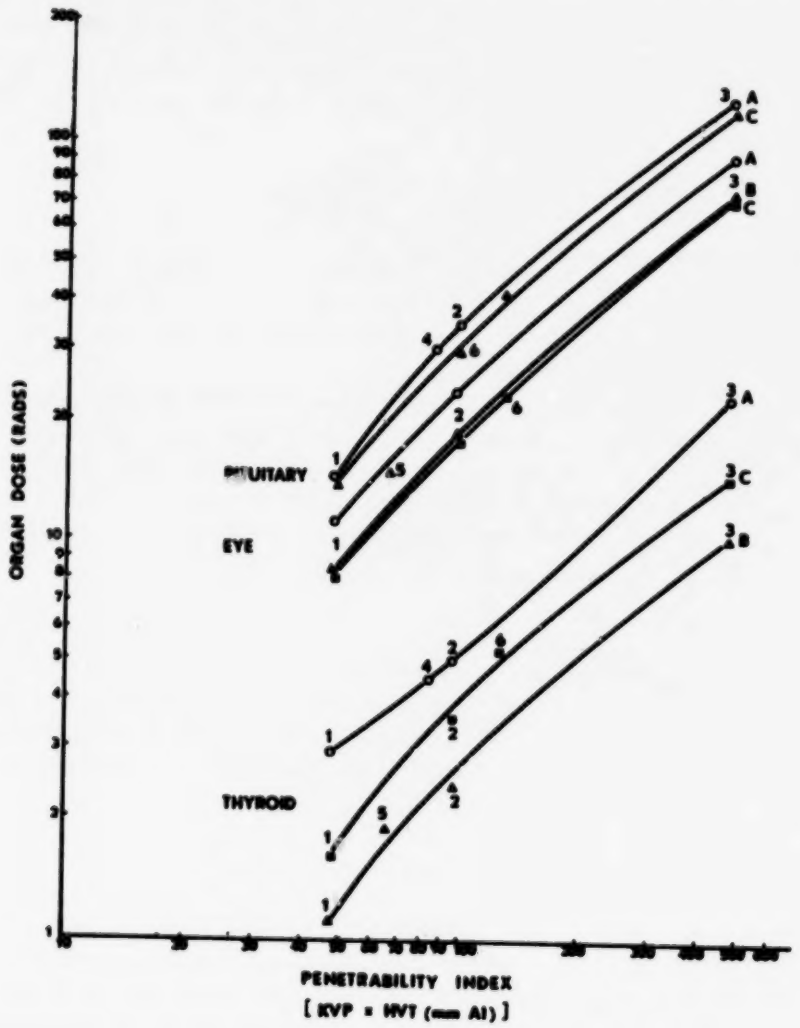


Figure 8. Doses to the eye, the thyroid, and the pituitary as functions of kVp and HVT. The penetrability index is defined as the product of kVp and HVT (in mm Al). Curves A, B, and C represent the 3, 6, and 12-year-old phantoms respectively. The numbers on the curves refer to the x-ray techniques as described in Fig. 6.

DISCUSSION

Statistical Analysis

This study is based primarily on the data of techniques 1, 2, and 3 (Fig. 6). Since phantom dosimetry is rarely subjected to statistical analysis, we felt that some further effort of this kind might be meaningful to the general field of phantom dosimetry. The statistical methods used are quite standard (16, 18).

The analytical objectives may be stated: To study the effect of skull age on brain dose as a mathematical function of an index of beam quality, and to determine the correlation between average brain dose and both eye and thyroid doses. A logarithmic transformation of the dose-kVp data was made to equalize the variances so that the "equal variance assumption" could be made and the least squares method applied. The empirical function fit was:

$$\ln(D) = b_0 + b_1 V + b_2 \ln(V)$$

where D is the dose (rad per 400 R per field), V is the tube potential (kVp), and the b's are constants. The constants were estimated by the least squares method for each brain section and for each entire brain.

When the data from the corresponding six sections were compared, the functions (different sets of parameters b_0, b_1, and b_2) differed significantly at the 1% level over skull age. However, when the entire brain was considered, the data did not show that the functions differ. It appears that the average dose of a large non-uniformly exposed organ has little or no meaning except in its use, such as to establish scaling factors as we have done.

The second test objective was to correlate brain-to-peripheral organ dose. No correlation coefficient smaller than 0.982 was found at the 1% level of significance. Thus, the correlations are quite strong, and the peripheral organ doses may be scaled as may the dosimeter sites in the brain.

Comparison with Previous Studies and Data Adjustments

Numerous investigators have reported on scalp dose distributions. Recently, Schulz and Albert (17) considered doses to the scalp, eye, brain, inner ear, and cranial marrow in a 9-year-old child head phantom. They also developed a model for calculating scalp dose distributions for various skull sizes and effective photon energies. Werner, Modan, and Davidoff (20) measured doses to the upper portion of the brain. In each of these studies, one phantom and one x-ray technique were used, and the phantoms differed in size and electron density. According to Modan and Levin (14), a majority of the children treated for tinea capitis were between the ages of 3 and 12 years.

Previous tinea capitis dosimetry by Shulz and Albert (17) showed that doses to the scalp ranged from 450 to 850 rads. Dose to the cranium marrow was estimated at about 400 rads in a 9-year-old head phantom irradiated by the Adamson-Kienbock technique under the following conditon: 100 kVp, 0.73 mm Al HVT (penetrability index = 73), 392 R per field, 25 cm SSD. Presswood was used as brain tissue equivalent material, and their reported mean brain dose was 140 rads. In order to compare their result with ours from Mix-D phantoms, we used ratios of the corresponding mass energy absorption coefficients and bulk densities of the different materials as approximate scaling factors and obtained an estimated mean brain dose of 98.6 rads. If their mean brain dose is further adjusted by use of the Mayneord F-factor for exposure per field and treatment distance different than our conditions of irradiation, their mean brain dose would be 98.2 rads (9). The estimated value for the mean brain dose in a 9-year-old child from Fig. 6 with the penetrability index of 73 is about 97 rads, which is in agreement with the adjusted value of Shulz and Albert within the limit of our experimental error.

The above example demonstrates the importance of the proper choice of tissue equivalent material in phantom dosimetry. Many phantom materials are currently used as "tissue equivalent" without qualifications in terms of their mass energy absorption coefficients and mass densities as compared to those of tissue. As demonstrated by the last example, different choices of phantom materials for brain tissue (presswood versus Mix-D) accounts for 42% discrepancy in dose to the brain.

REFERENCES

1. Albert, R.E., and A.R. Omran. Follow-up study of patients treated by x-ray epilation for tinea capitis. Arch. Environ. Health 10:899 (1968).

2. Berger, R.T. The x- or gamma-ray energy absorption or transfer coefficients: tabulation and discussion. Radiation Res. 15:1 (1961).

3. Cipollaro, A.C., A. Kallos, and J.P. Ruppe, Jr. Measurement of gonadal radiation during treatment for tinea capitis. J. Med. 59:3033 (1959).

4. Clarkson, J.R., and W.V. Mayneord. The "quality" of high voltage radiations, Part II. "Quality" within a scattering medium. Brit. J. Radiol. 12:168 (1939).

5. Combes, F.C., and H.T. Behrman. Technic and problems of roentgen ray epilation. Arch. Dermatol. Syph. 57:74 (1948).

6. Depth Dose Tables for Use in Radiotherapy. Brit. J. Radiol. Supp. 10, Brit. Inst. Radiol, London (1961).

7. Greening, J.R. The derivation of approximate x-ray spectral distributions and an analysis of x-ray "quality" specifications. Brit. J. Radiol. 36:363 (1963).

8. International Commission on Radiological Units and Measurements. Physical aspects of irradiation, ICRU Report 10b, 1962. NBS Handbook 85, U.S. Department of Commerce (March 31, 1964).

9. Johns, H.E. The Physics of Radiology, p. 340. Charles C. Thomas, Springfield, Ill. (1969).

10. Jones, D.E.A., and H.C. Raine. Correspondence. Brit. J. Radiol. 22:549 (1949).

11. Loevinger, R., and S.S. Yaniv. Absorbed dose determination for x-rays in the grenz-ray region (5 to 20 keV quantum energy). Phys. Med. Biol. 10:213 (1965).

12. Long, C. Biochemist Handbook, p. 642. Van Nostrand, Princeton, N. J. (1961).

13. Manes, J.D., R.P. Chiacchierini, and H.D. Youmans. Chromatographic analysis of the lipids of beagle pup brain exposed in vivo to x radiation. In Radiation Biology of the Fetal and Juvenile Mammal, p. 877. U.S. Atomic Energy Commission, Division of Technical Information, CONF 690501 (1969).

14. Modan, E., and S. Levin. Private communication (1969).

15. Proctor, N.M., and J.R. Greening. On the adequacy of half-value layer as a criterion of x-ray quality in the calibration of dosemeters. Brit. J. Radiol. 33:321 (1960).

16. Rao, C. Advanced Statistical Methods in Biometric Research, p. 112-155. John Wiley and Sons, New York (1952).

17. Shulz, R.J., and R.E. Albert. Dose to organs of the head from the x-ray treatment of tinea capitis. Arch. Environ. Health 17:935 (1968).

18. Snedecor, W. Statistical Methods, p. 149. Iowa State College Press, Ames (1946).

19. Walter, J., and M. Miller. Radiotherapy, p. 351. The Blackiston Company, Philadelphia (1950).

20. Werner, A., B. Modan, and D. Davidoff. Doses to brain, skull, and thyroid following x-ray therapy for tinea capitis. Phys. Med. Biol. 13:247 (1968).

21. Zugerman, I. Early reactions following roentgen ray epilations. Arch. Dermatol. Syph. 60:722 (1949).

* U. S. GOVERNMENT PRINTING OFFICE : 1970—436-615/75

The ABSTRACT CARDS below are designed to facilitate document retrieval using Coordinate Indexing. They provide space for an accession number (to be filled in by the user), suggested key words, bibliographic information, and an abstract.

The Coordinate Index concept of reference material filing is readily adaptable to a variety of filing systems. Coordinate Indexing is described in the publication "IBM Data Processing Techniques - Index Organization for Information Retrieval" (C 20-8062). Copies are available through IBM Branch Offices.

The cards are furnished in triplicate to allow for flexibility in their use (e.g., author card index, accession number card index).

DOSES TO THE CENTRAL NERVOUS SYSTEM OF CHILDREN RESULTING FROM X-RAY THERAPY FOR TINEA CAPITIS (BRH/DBE 70-4).

Wah Lee and H.D. Youmans, October 1970. Division of Biological Effects, Bureau of Radiological Health, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Maryland 20852.

X-ray beam qualities of 72-118 kVp with HVT's of 0.66-3.9 mm Al were used to irradiate three head phantoms constructed from the skulls of 3-, 6-, and 12-year-old children using Mix D as soft tissue equivalent material. Thermoluminescent dosimeters were used for "in phantom" exposure measurements. A relatively simple method was

(over)

DOSES TO THE CENTRAL NERVOUS SYSTEM OF CHILDREN RESULTING FROM X-RAY THERAPY FOR TINEA CAPITIS (BRH/DBE 70-4).

Wah Lee and H.D. Youmans, October 1970. Division of Biological Effects, Bureau of Radiological Health, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Maryland 20852.

X-ray beam qualities of 72-118 kVp with HVT's of 0.66-3.9 mm Al were used to irradiate three head phantoms constructed from the skulls of 3-, 6-, and 12-year-old children using Mix D as soft tissue equivalent material. Thermoluminescent dosimeters were used for "in phantom" exposure measurements. A relatively simple method was

(over)

DOSES TO THE CENTRAL NERVOUS SYSTEM OF CHILDREN RESULTING FROM X-RAY THERAPY FOR TINEA CAPITIS (BRH/DBE 70-4).

Wah Lee and H.D. Youmans, October 1970. Division of Biological Effects, Bureau of Radiological Health, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Maryland 20852.

X-ray beam qualities of 72-118 kVp with HVT's of 0.66-3.9 mm Al were used to irradiate three head phantoms constructed from the skulls of 3-, 6-, and 12-year-old children using Mix D as soft tissue equivalent material. Thermoluminescent dosimeters were used for "in phantom" exposure measurements. A relatively simple method was

(over)

developed which yields an accurate estimation of dose distribution in the brain and doses to the eye and thyroid of children (ages 3-12) irradiated with any x-ray technique commonly employed for the treatment of tinea capitis. Typical ranges of doses to the organs of the head are: brain, 100-200 rads; lens of eye, 10-25 rads; and thyroid, 2-5 rads.

KEY WORDS: x-ray dose; tinea capitis; brain-, eye-, thyroid-dose; thermoluminescent dosimetry; human exposure

developed which yields an accurate estimation of dose distribution in the brain and doses to the eye and thyroid of children (ages 3-12) irradiated with any x-ray technique commonly employed for the treatment of tinea capitis. Typical ranges of doses to the organs of the head are: brain, 100-200 rads; lens of eye, 10-25 rads; and thyroid, 2-5 rads.

KEY WORDS: x-ray dose; tinea capitis; brain-, eye-, thyroid-dose; thermoluminescent dosimetry; human exposure

developed which yields an accurate estimation of dose distribution in the brain and doses to the eye and thyroid of children (ages 3-12) irradiated with any x-ray technique commonly employed for the treatment of tinea capitis. Typical ranges of doses to the organs of the head are: brain, 100-200 rads; lens of eye, 10-25 rads; and thyroid, 2-5 rads.

KEY WORDS: x-ray dose; tinea capitis; brain-, eye-, thyroid-dose; thermoluminescent dosimetry; human exposure